REPORT R-1750

COMBUSTIBLE AMMUNITION FOR SMALL ARMS
IV. Development of Improved Obturator Devices for Caseless Ammunition

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January 1965

AMCMS Code 5530.11.553

UNITED STATES ARMY
FRANKFORD ARSENAL
RESEARCH & DEVELOPMENT DIRECTORATE

PHILADELPHIA, PA. 19137

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AMCMS Code 5530.11.553
DA Project 1C523801A293

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FRANKFORD ARSENAL
Philadelphia, Pa. 19137

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ABSTRACT

An obturator, reusable for approximately 60 firings of 7.62 mm caseless ammunition, was designed, fabricated, and evaluated. This obturator consisted of two metal split rings with a neoprene O-ring positioned between them. A 7.62 mm caseless test weapon (Model 4) was designed and fabricated for this investigation, and a Springfield 1903 rifle was similarly modified for shoulder firing 7.62 mm caseless ammunition before the U.S. Army Infantry Board during June 1962.

A combination obturator/firing pin projectile (designated "Bulpin") was designed, fabricated, and evaluated for caliber .30 caseless solid propellant ammunition. Two such Bulpin projectiles, one in front of a bore-size caseless charge containing a combustible primer and one behind it for ignition and obturation, provided a solid propellant caseless system which used a new firing pin and seal for each firing. After each firing, the rear projectile was pushed forward by the next Bulpin round for use as the next projectile.

There are indications that, in caseless solid propellant ammunition, the increased ratio of propellant charge length to propellant charge diameter results in lower projectile velocity and higher peak pressure and that increased molding pressure in the forming of the propellant results in higher velocity and higher peak pressure.

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INTRODUCTION

The test firing of 7.62 mm caseless ammunition, as it evolved from the split-case round, through the stub-obturated cartridge, to the totally combustible caseless round of the present, required a self-sealing test weapon.[1,2*] Investigations directed toward this goal resulted in the development of such a test weapon and a modified M14 rifle capable of single shot fire.[2,3]

The test weapon, based on a reverse tapered firing pin action, depended on primer pressure to seat the pin and effect the obturation of the chamber, but an inherent disadvantage in this system permitted the chamber to be unsealed at the moment of ignition. The modified M14 rifle employed an expandable brass cup obturator which had to be replaced after each firing.

The above investigations indicated that an obturator was needed which would: (1) provide the chamber with a positive seal prior to ignition; (2) function at the required operating pressures (50,000 to 60,000 psi); and (3) be reusable if repetitive firing of caseless ammunition was to be achieved. The work described herein covers the period September 1962 to August 1963, and was directed toward obtaining a reusable obturator. Two methods of obturation, based on neoprene O-ring sealing, were explored.

The initial work consisted of designing, fabricating, and evaluating a caliber .30 caseless round using O-ring seals and a self-contained firing pin within the projectile. In the subsequent investigation, the concept of O-ring obturated projectiles was applied to the bolt and firing pin of a 1903 rifle. By adding metal split rings to the system, a tricomponent obturator was realized which could be used for approximately 60 firings without replacement.

PROJECTILE DEVELOPMENT

Olin Mathieson Chemical Corporation[4] had developed a caliber .30 primed projectile configuration for a caseless liquid propellant/dual projectile gun system which adequately sealed the gun chamber, both in the breech and in the forward position, during firing of the subsequent round. Sealing was accomplished by means of two 1/32 inch sectional diameter O-rings around the projectile and by the primer cup in the base of the projectile. The primer gases ignited the liquid propellant by venting through a flash tube located axially in the projectile. This primed caliber .30 projectile is illustrated in Figure 1.

*See REFERENCES.

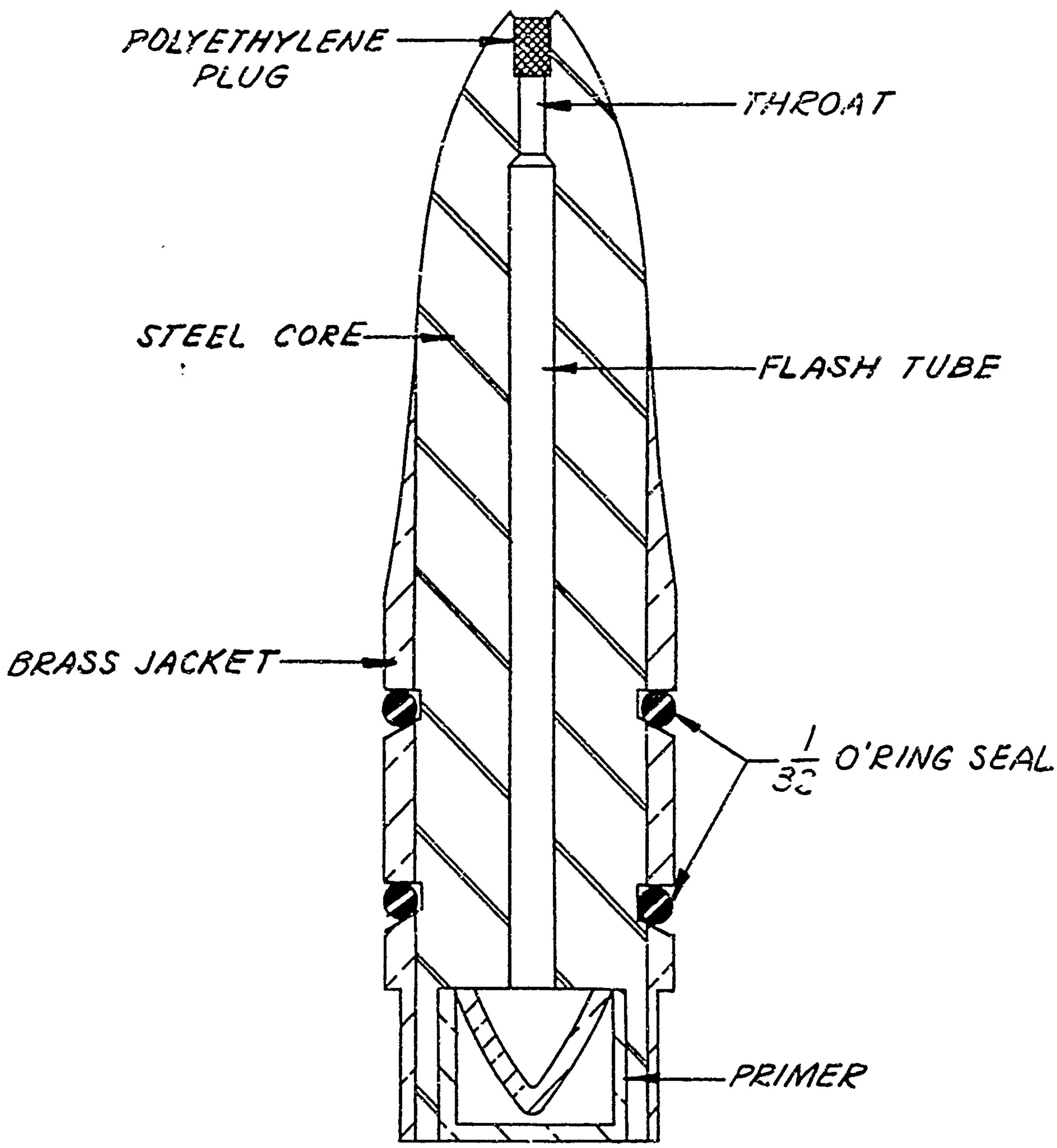


Figure [illegible]. Caliber .30 Primed Projectile

In the liquid propellant/dual projectile gun system, two projectiles are positioned in the chamber, one (with its spent primer) in front of the liquid propellant charge, and the other (with a live primer) behind the charge at the breech of the gun. After firing, the rear projectile with its then spent primer, is mechanically moved to the forward position to be fired.

Before adapting the caseless liquid propellant/dual projectile approach to a caseless solid propellant cartridge, the obturating method of which could be transferred to a conventional bolt, it was believed that the primer in the projectile would have to be eliminated. Undesirably extensive and expensive redesign of projectile base and primer metal components would be necessary if the primer-flash tube method of ignition was to be used with a solid propellant charge. However, in place of the primer, a firing pin was designed that extended from the base of the projectile to its point. This caseless, solid propellant, self-obturating projectile with the expendable firing pin (illustrated in Figure 2) was designated the "Bulpin" projectile.

Figure 3 is a photograph of a Bulpin round ready to be fired. It shows a caseless charge, with a combustible dual primer recessed at its base, positioned between two Bulpin projectiles. The forward projectile firing pin has already been actuated, while the rear projectile firing pin is retraced.

Projectile

The original liquid propellant, caseless, primed projectile was modified as illustrated in Figure 2. Its primer flash tube was widened to permit insertion of the firing pin. A small steel spring was positioned between the firing pin head and the base of the projectile cavity. This permitted the projectile's firing pin to travel 0.030 inch. Obturation was accomplished by covering the firing pin cavity in the projectile with an obturating cup and by equipping the projectile with two neoprene O-rings.

Caseless Test Weapon

To evaluate the Bulpin round, a test weapon was fabricated as illustrated in Figure 4. The chamber was cylindrical, having a volume of 0.181 cubic inch (identical to the 7.62 mm NATO case volume) calculated from the last O-ring on the forward projectile to the first

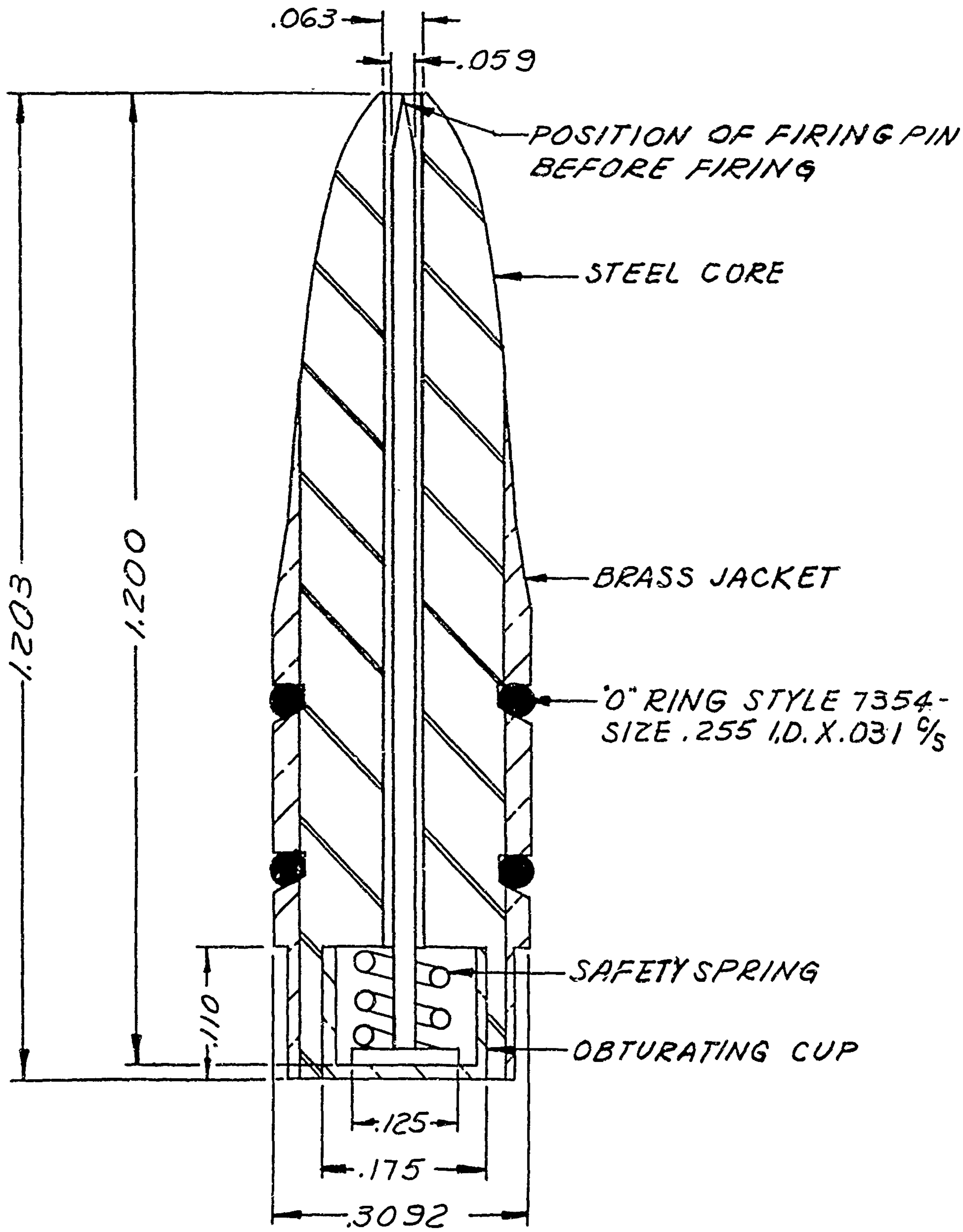


Figure 2. Bulpin Projectile

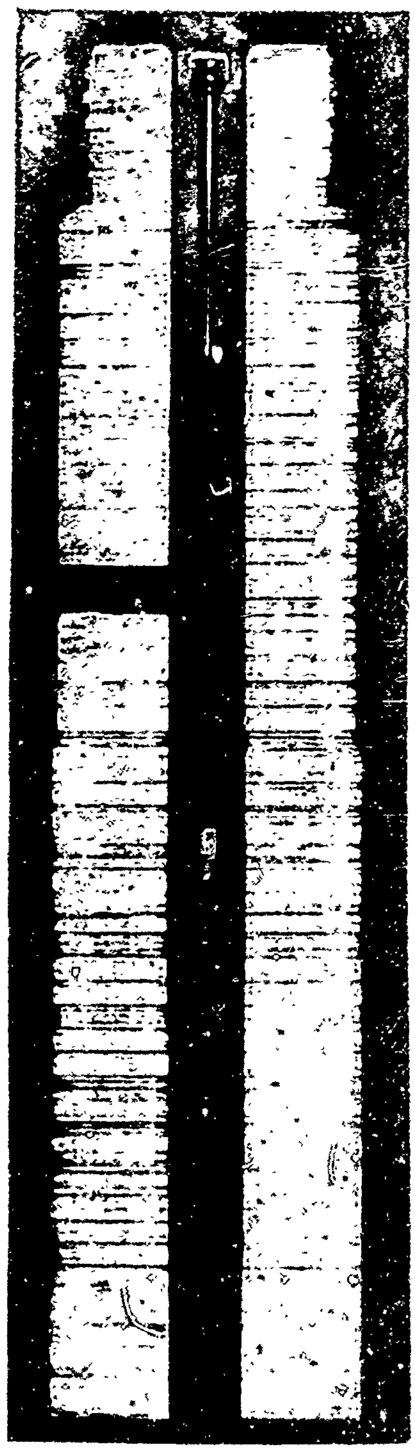


Figure 3. Sectional view of a Chambered Bulpin Round

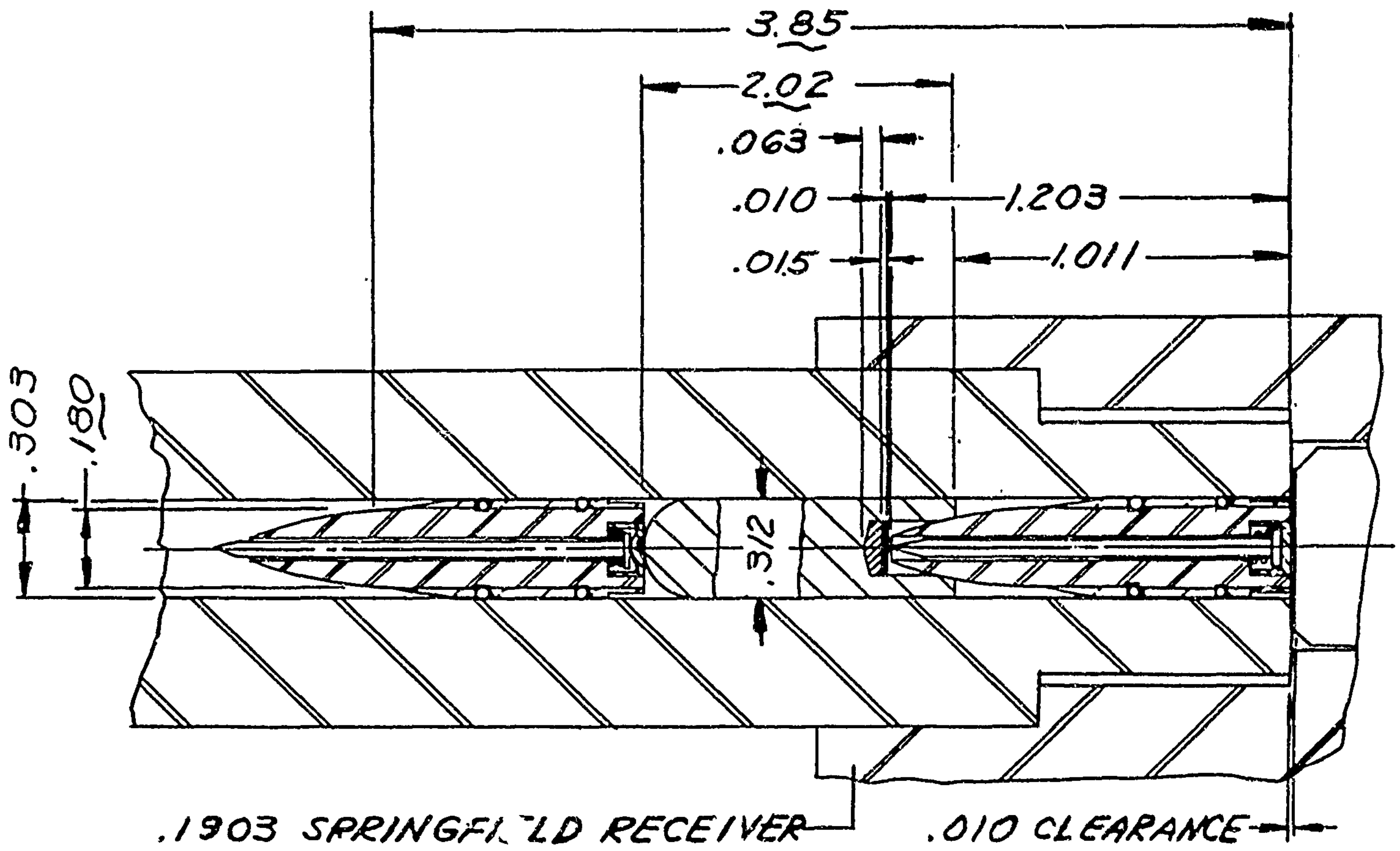


Figure 4. Bulpin Test Weapon (Model 3) and Dimensioned Round

O-ring on the rear projectile. This weapon was fitted with a Springfield 1903 receiver, the bolt of which required two minor modifications - removal of the extractor and grinding the bolt face flush to provide a 0.010 inch headspace.

Caseless Round

The dual projectile approach dictated that the caseless charge should be bore size or smaller. A cylindrical caseless charge was fabricated from IMR 4895 propellant, and the primer pocket was recessed in order to permit a 0.015 inch clearance between the combustible primer and the rear projectile. The primer was a duplex combustible primer[2] consisting of 0.50 grain 959 primer mix with a 0.10 grain supersensitive topping mix.

Ballistic Evaluation

Forty-one Bulpin rounds were fired. With this limited number of rounds it was possible to determine that the self-contained firing pin in the projectile, after being energized by the bolt's firing pin, could ignite the combustible primer without difficulty, and that the O-rings on the projectiles sealed properly. All projectiles, except the initial and the last, were used first as firing pin and obturator, and then as a projectile.

The slight protrusion (0.030 inch) of the firing pin was found not to affect the accuracy of the Bulpin projectile. At 100 yards, its linear standard deviation was determined to be 0.30 mil. This is comparable to the accuracy of the caliber .30 M2 projectile. Ballistic reproducibility of the Bulpin round was very good. Results are listed in Table I.

A high length/diameter (L/D) is inherent in any bore diameter caseless round design, and the higher the L/D ratio, the more we approach the conditions of a closed chamber. It will be noted in Table I that the average peak pressure is up to the maximum allowable, in terms of NATO requirements, but the velocity is about 100 fps less than that of standard cased ammunition. The fact that large L/D charge ratios are inherently associated with low velocity peak pressure ratios suggested that low L/D chamber ratios might give high velocity peak pressure ratios, which are highly desirable.

TABLE I. Ballistic Evaluation of Bulpin Caseless Ammunition

Charge: 42.0 ± 0.25 gr IMR 4895 Propellant
L/D : 7.4

	Velocity at 78 Feet (fps)	Pressure (Copper) (psi)
	2690	45,300
	2640	50,600
	2665	-
	2665	54,900
	2645	51,700
	2646	52,000
	2616	55,700
	2633	47,900
	2667	51,600
Avg	2652	51,200
Std Dev	21	3,200

The advantage of the Bulpin type of round lies in its elimination of two problems inherent with combustible ammunition, viz., sealing of the breech of the gun and erosion of the firing pin and bolt face. However, there are two disadvantages evident with this type round - the design of the tracer projectile (which would be difficult, but not impossible) and, the major disadvantage, the unconventional method required to feed this round.

The Bulpin caseless round was not explored further, primarily due to the lack of an automatic weapon that could be converted to fire solid propellant caseless ammunition. It was therefore decided to apply the rubber O-ring sealing approach to a single shot conventional weapon in order to study methods of extending the life of the rubber O-ring seals.

METAL SPLIT RING/RUBBER O-RING OBTURATOR

Before methods of extending O-ring life could be investigated, it was necessary to design a test weapon which would permit sealing by means of O-rings. Because of their ability to withstand a high degree of thrust, the 1903 Springfield bolt and receiver were selected for this purpose. Also, such an approach would permit future modification of a Springfield 1903 rifle for shoulder firing of

caseless ammunition. (A Springfield 1903 rifle was modified for that purpose at the conclusion of this investigation.) The Springfield 1903 "caseless" test weapon is illustrated in Figure 5.

Test Weapon

Design

An adapter which could be secured by set screws was designed for the Springfield 1903 bolt. O-rings were positioned on the adapter and its firing pin. Figures 6 and 7 show this and the other modifications.

Sealing

At the high operating chamber pressures (50,000 to 60,000 psi) which are reached in small arms weapons, the clearances in the O-ring sealing area are very important. If the clearance were too large, it would be possible for the O-ring to fail immediately. Consequently, the clearances on the diameters in the sealing area were kept to 0.002 inch. As an example, the outside diameter of the firing pin, where the O-ring sealed, was 0.298 inch and the bore diameter of the adapter was 0.300 inch. These seals had to be replaced after five or six firings, as even with these small clearances, the O-rings still extruded and finally ripped.

To prevent extrusion, the clearance behind the O-rings was eliminated by means of split (or back-up) rings. Before doing this, however, it was necessary to decrease the inside diameter of the firing pin O-ring groove for a larger sectional diameter O-ring (0.070 inch sectional diameter) in order that commercially available back-up rings could be used on the firing pin. For positioning the back-up rings, both the adapter and firing pin O-ring groove widths had to be increased from 0.090 to 0.215 inch.

Standard teflon and leather back-up rings were evaluated and both types extruded after five to six firings and had to be replaced. Metal split rings were then fabricated from copper-beryllium bar stock. To mount these rings, slight modifications had to be made to both the adapter and the firing pin. In the face of the adapter, a cut (0.090 inch) was made through which the rings were spiraled on. The firing pin was made in two parts and was threaded together at the forward section of the O-ring groove. Two metal split rings were positioned on both pieces, with an O-ring positioned between them. They were arranged in this manner so that the first metal split ring would keep flame and combustion products of the primer away from the

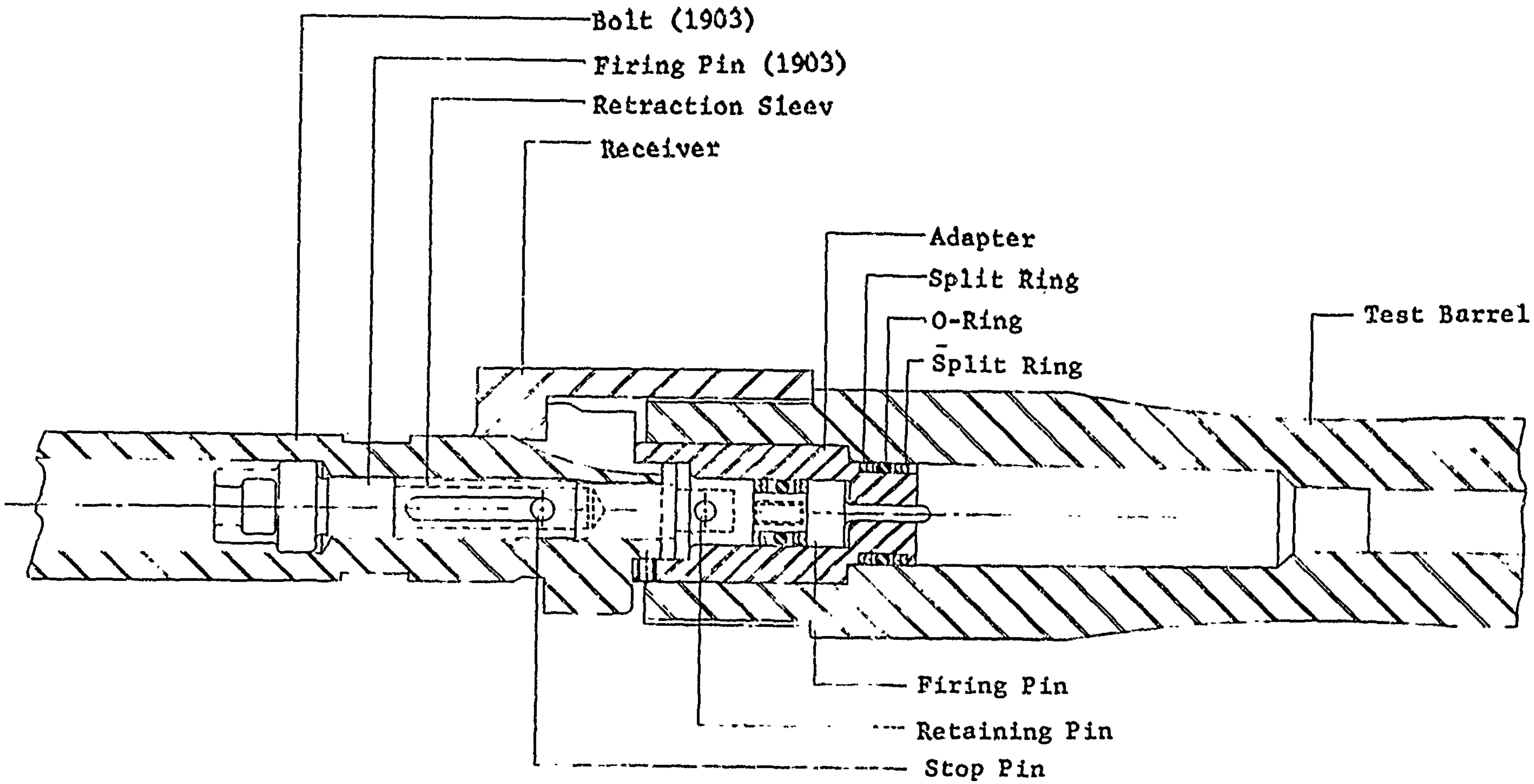


Figure 5. Springfield 1903 "Caseless" Test Weapon (Model 4)

Modified

Standard

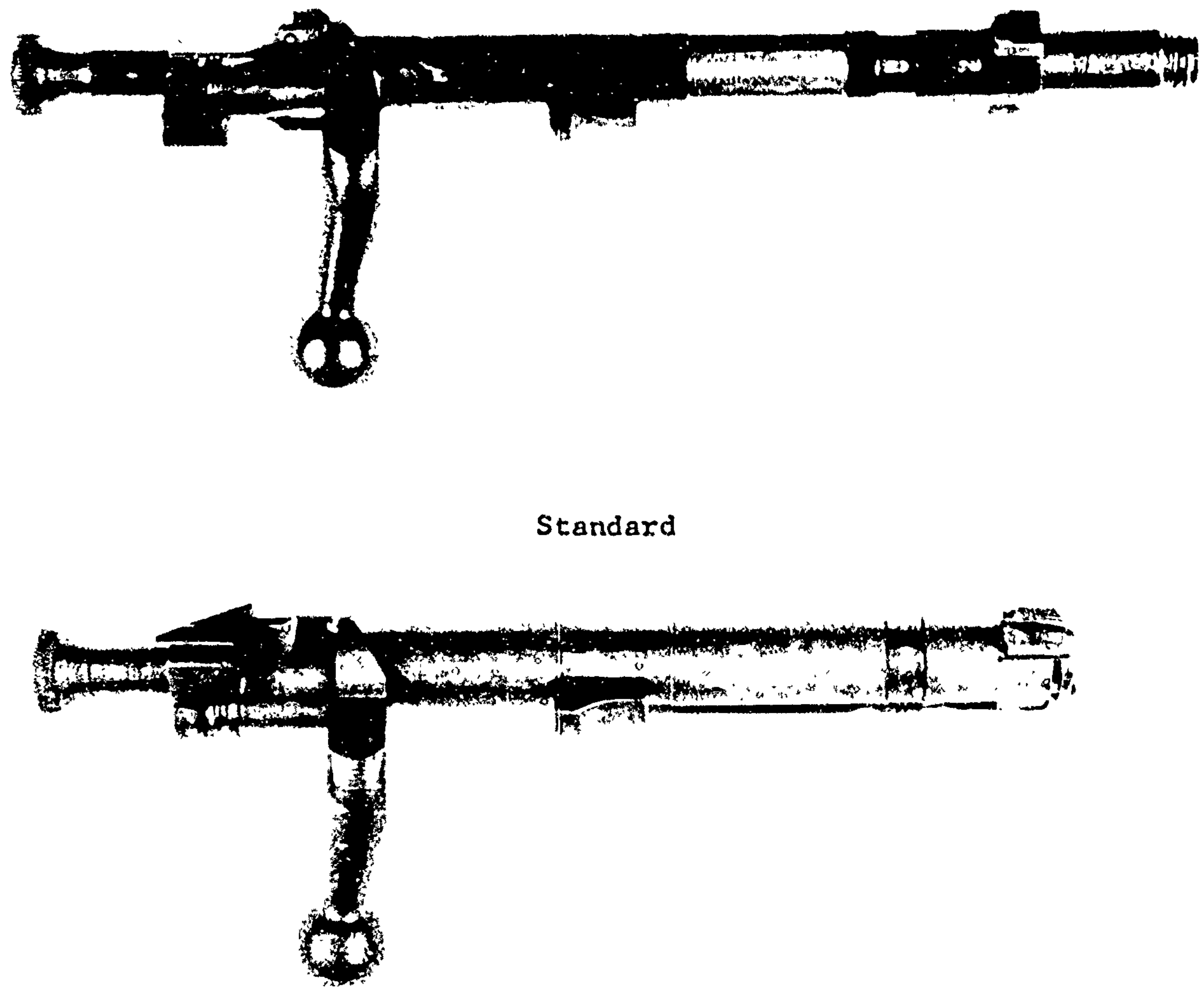
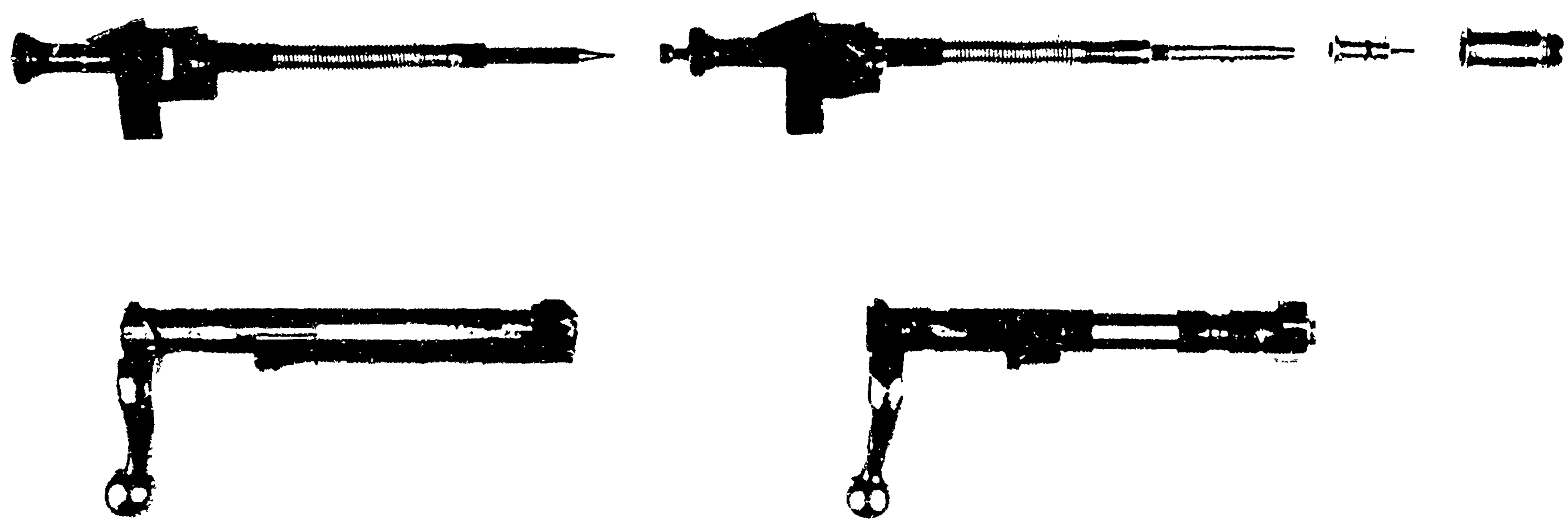


Figure 6. Springfield 1903 Bolt Assemblies - Assembled view



Standard Modified

Figure 7. Springfield 1903 Bolt Assemblies - Unassembled view

O-ring and the rear ring would prevent extrusion. An assembly drawing of the test weapon (Model 4) with the metal split ring/O-ring obturator on the adapter and the firing pin is shown in Figure 5; the metal split ring is illustrated in Figure 8.

The metal split ring/O-ring obturator extended the life of the O-ring to approximately 60 firings at pressures around 50,000 psi. After this number of firings, the expansion properties of the soft copper-beryllium split rings were gone. The outside diameter of the metal split ring then decreased until a clearance resulted in the sealing area, into which the O-ring extruded.

Erosion

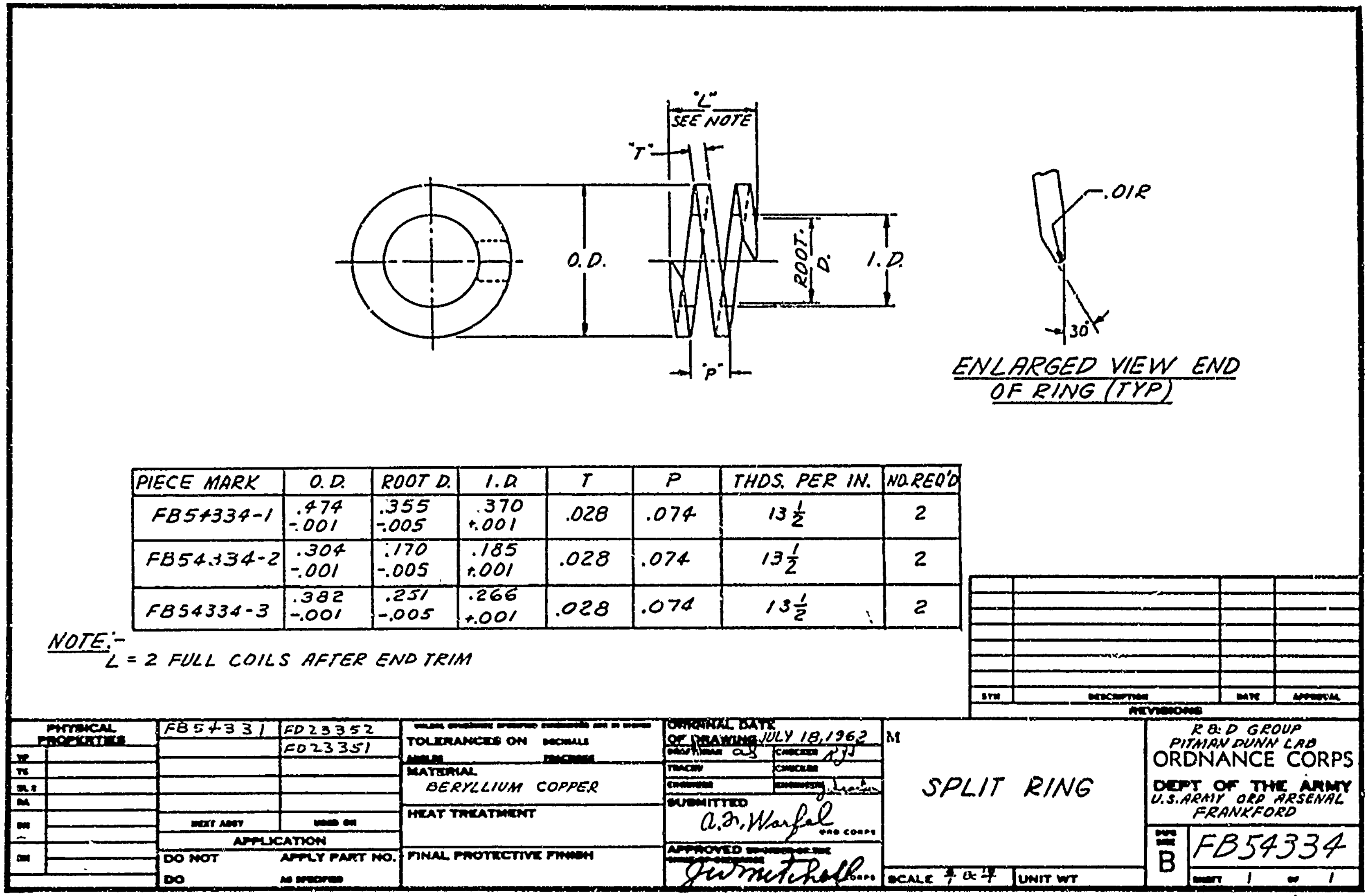
After approximately 60 firings, both the firing pin and the firing pin hole in the face of the adapter had eroded considerably. For example, the pin protrusion of the firing pin decreased from 0.065 inch to approximately 0.040 or 0.035 inch. Misfires resulted, due to the reduced pin protrusion. The diameter of the firing pin hole increased from 0.080 to 0.095 inch. Thus, the entire adapter assembly, which included firing pin and obturators, had to be replaced.

Springfield 1903 "Caseless" Rifle

At the conclusion of the development of the test weapon phase, a request was received from the U.S. Army Infantry Board, Fort Benning, Georgia, for a shoulder-fired demonstration of 7.62 mm caseless ammunition. For this purpose, a Springfield 1903 rifle was redesigned and modified similarly to the test weapon. This caseless rifle is illustrated in Figure 9.

Two improvements were incorporated in the Springfield 1903 rifle. The sealing clearances were increased from 0.002 to 0.005 inch on the diameters. The metal split ring diameters were also increased by 0.003 inch to compensate for this increase. The increased clearances facilitated insertion and extraction of sealing parts.

The other improvement permitted retraction of the firing pin upon opening and closing the bolt. In the test weapon, this was accomplished by exerting force on the tip of the firing pin. The modification for retracting the adapter firing pin consisted of connecting it to the bolt firing pin by means of a sleeve. (This is illustrated in Figure 5.)



PIECE MARK	O.D.	ROOT D.	I.D.	T	P	THDS. PER IN.	NO. REQ'D
FB54334-1	.474 -.001	.355 -.005	.370 +.001	.028	.074	13 1/2	2
FB54334-2	.304 -.001	.170 -.005	.185 +.001	.028	.074	13 1/2	2
FB54334-3	.382 -.001	.251 -.005	.266 +.001	.028	.074	13 1/2	2

Figure 8. Split Ring

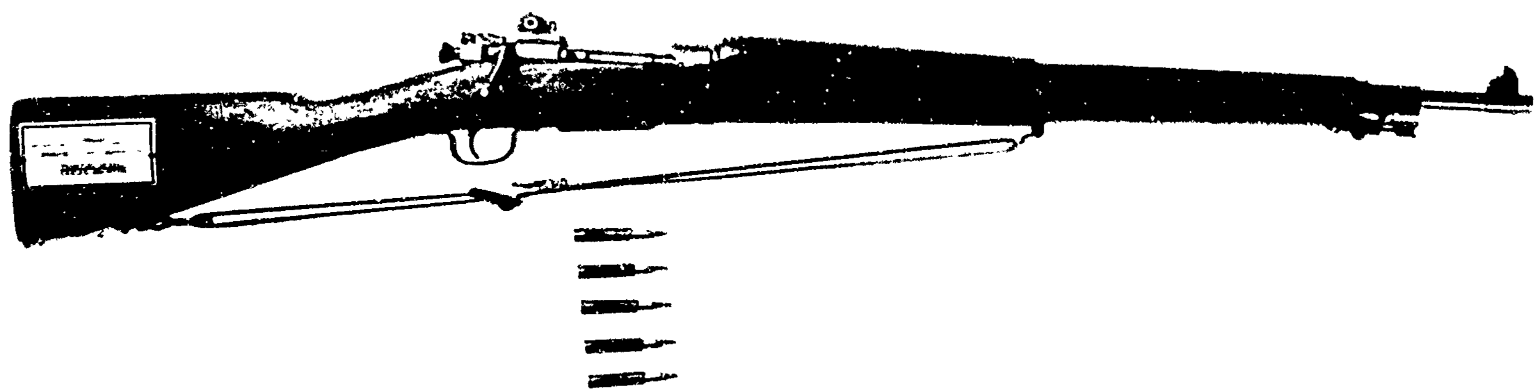


Figure 9. Springfield 1903 "Caseless" Rifle

Seventeen 7.62 mm caseless rounds were fired with the modified Springfield 1903 rifle without malfunction before the U.S. Army Infantry Board during June 1962.

7.62 mm Caseless Round

The 7.62 mm caseless round with the M59 projectile, used for this investigation, was similar to the previous type round[2] except that its charge weight was reduced from 59 to 49 grains and the primer weight was increased from 0.6 to 0.98 grain. The propellant was IMR 4895, with nitrocellulose (pyroxylin) dissolved in ether-alcohol as the binder. The combustible primer was a dual primer system[2] containing 0.9 grain lead styphnate mix with a commercially available, approximately 0.9 grain, percussion-sensitive cap bonded to a styphnate pellet. The 7.62 mm caseless round used in this investigation is illustrated in Figures 10 and 11.

Caseless charges pressed at 2500 and 3700 psi were evaluated in order to determine the effect of the pressing on the ballistics. The rounds pressed at 3700 psi produced higher velocities and pressures than the rounds pressed at 2500 psi with identical charge (49 grains) and primer (0.98 grain) weights. Table II lists the ballistic results of this evaluation.

The fact that a higher ballistic performance was achieved with the caseless rounds pressed at 3700 psi over those pressed at 2500 psi merits some explanation. It is suggested that the pressure differential is, in itself, not the main cause (although none the less important), but that, after the pressing operation, the residual binder in the molded unified charge is the principal factor. The binder used in both types was the same and consisted of low energy nitrocellulose (7 to 10% N) and camphor dissolved in a 50/50 mixture of ethyl alcohol and ether. The excess binder used in the charging operation is removed when the combination of propellant granules and binder are compression-molded. It has not been verified but it is believed that charges pressed at the lower pressure retain more of the binder than do those pressed at the higher pressure. If this is so, then the charges pressed at 2500 psi retained more of the less energetic binder solids with the following possible effects:

(1) A less energetic molded propellant charge would result and, thus, lower pressures and velocities would be yielded.

(2) A less brittle and more plasticized molded propellant charge would result and thus, upon primer impact, larger granular aggregates and fewer propellant particles would result in a correspondingly decreased surface area. The propellant would take longer

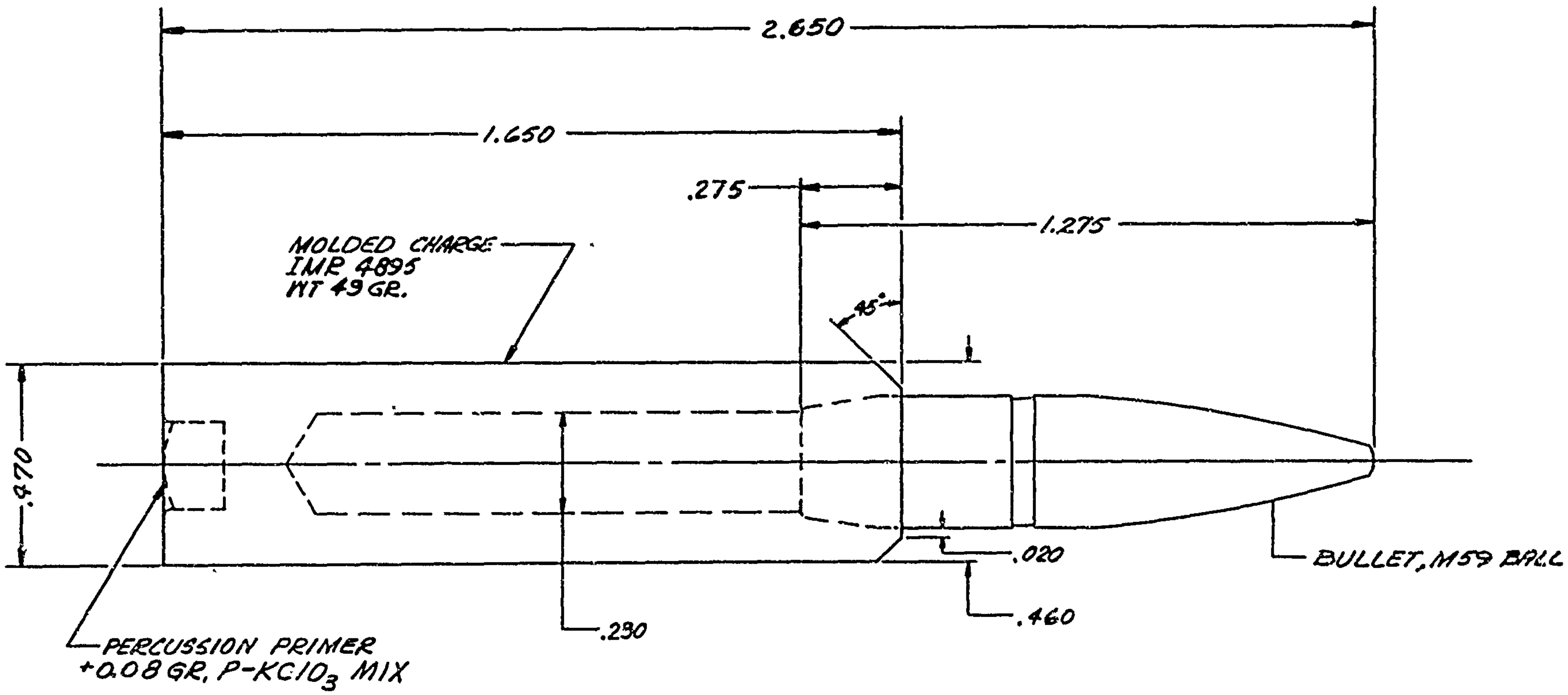


Figure 10. Dimensioned 7.62 mm Caseless Ammunition Used with Frankford Arsenal Modified Springfield 1903 Rifle

Figure 11. 7.62 mm Caseless Ammunition for Use with Frankford Arsenal Modified Springfield 1903 Rifle

TABLE II. Evaluation of Caseless Rounds Pressed at 2500 and 3700 psi

Charge: 49.2 ± 0.20 grains IMR ~~4859~~ 4895 Propellant

	Velocity at 78 Feet (fps)	Peak Piezo Pressure (psi)	Time (msec)	
			Propellant Ignition	Barrel
		Rounds Pressed at 3700 psi		
	2713	46,500	0.25	1.40
	2798	53,000	0.20	1.25
	2839	55,800	0.05	1.00
	2761	50,200	0.10	1.20
	2820	55,800	0.10	1.20
	2798	54,900	0.10	1.05
	2842	54,900	0.10	1.10
	2728	46,500	0.15	1.20
	2801	52,100	0.05	1.20
	2777	50,200	0.20	1.25
Avg	2787	52,000	0.13	1.19
Std Dev	41	3,430	0.06	0.11
		Rounds Pressed at 2500 psi		
	2506	36,300	0.55	1.90
	2481	37,200	0.15	1.45
	2456	35,300	0.45	1.75
	2573	37,200	0.20	1.55
	2444	36,300	0.55	1.90
	2429	33,500	0.35	1.70
	2512	35,300	0.20	1.50
	2556	38,100	0.55	1.80
	2383	30,700	0.40	1.85
	2554	37,200	0.60	1.90
Avg	2489	35,700	0.40	1.73
Std Dev	63	2,340	0.16	0.17

to be consumed and, thereby, would result in lower pressures and velocities. The longer propellant ignition and barrel times indicate this possibility.

These are some possible reasons for the results obtained. Only a complete study of the effect of molding pressure-dwell time-temperature relationships of the two-phase liquid-solid propellant system would reveal whether or not the desired ballistics could be "molded" into caseless ammunition.

CONCLUSIONS

An obturator, reusable for approximately 60 firings of 7.62 mm caseless ammunition, was designed, fabricated, and evaluated. The obturator consisted of two metal split rings with a neoprene O-ring positioned between them. A 7.62 mm test weapon (Model 4) was designed and fabricated for this investigation. A Springfield 1903 rifle was modified similar to the test weapon for shoulder firing 7.62 mm caseless ammunition before the U.S. Army Infantry Board.

A Bulpin projectile (that is, a combination obturator/firing pin projectile) was designed, fabricated, and evaluated for caliber .30 caseless solid propellant ammunition. Two Bulpin projectiles, one in front of a bore-size caseless charge containing a combustible primer and one behind it for ignition and obturation, provided a solid propellant caseless system which used a new firing pin and seal for each firing. The rear projectile, after each firing, was pushed forward by the next Bulpin round, to be used as a projectile.

There are indications that, in caseless solid propellant ammunition, the increased ratio of propellant charge length to propellant charge diameter results in lower projectile velocity and higher peak pressures, and that increased molding pressure in the forming of the propellant results in higher velocity and higher peak pressure.

RECOMMENDATIONS

1. The geometries of both the rifle chamber and the caseless cartridge should be investigated in order to optimize the ballistic performance of the 7.62 mm caseless system.

2. Studies should be conducted to evaluate, extensively, the effect of propellant molding pressure on the ballistic performance of caseless ammunition.

3. An M14 rifle should be modified to fire caseless ammunition, employing the metal split ring/O-ring obturating device described in this report.

4. An investigation should be conducted to increase the life of the obturator. New materials should be sought for the O-ring and, also, for the metal split ring.

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REPRODUCTION BRANCH
FRANKFORD ARSENAL
Date Printed: 3/18/65

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) FRANKFORD ARSENAL Philadelphia, Pa. 19137 (SMUFA 1214	2a REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP NA

3 REPORT TITLE

COMBUSTIBLE AMMUNITION FOR SMALL ARMS.
IV. Development of Improved Obturator Devices for Caseless Ammunition

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Research Report - Jan 62 thru Aug 63

5 AUTHOR(S) (Last name, first name, initial)

SCANLON, John J.
QUINLAN, Joseph B.
VANARTSDALEN, Earl F.

6 REPORT DATE	7a TOTAL NO. OF PAGES	7b NO. OF REFS
January 1965	22	Four

8a. CONTRACT OR GRANT NO. AMCMS Code 5530.11.553 b. PROJECT NO. DA Proj 1C523801A293 c d.	9a. ORIGINATOR'S REPORT NUMBER(S) R-1750 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	AMCRD-DE-W

13 ABSTRACT

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DD FORM 1 JAN 64 1473

Security Classification

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Propellant						
Ammunition, Caseless						
Primer						
Weapon, Caseless Ammunition						

INSTRUCTIONS

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